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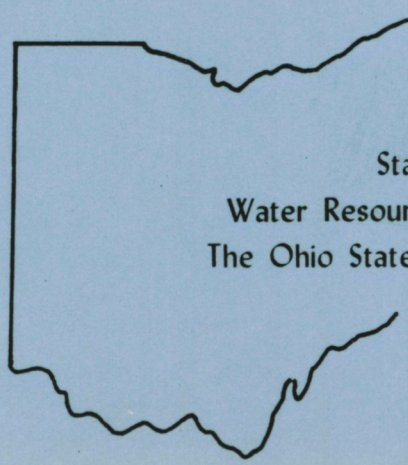
Report No. G-1607-02

FISCAL YEAR 1989 PROGRAM REPORT

Robert C. Stiefel
Director

United States
Geological Survey



State of Ohio
Water Resources Center
The Ohio State University

Report No.
G-1607-02

FISCAL YEAR 1989 PROGRAM REPORT

Grant No. 14-08-0001-G1607

for

U. S. Department of the Interior
Geological Survey

by

Water Resources Center
The Ohio State University
Columbus, Ohio 43210

Robert C. Stiefel, Director

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ABSTRACT

Water is one of Ohio's most important natural resources, and the State has an adequate supply to meet its immediate needs. Most of Ohio's water problems are associated with water quality. Of primary concern are the sediments, nutrients and acids in the surface waters from urban, agricultural and mining areas, and the toxic and hazardous wastes that threaten the ground and surface waters. The focus of the 1989 State Water Research Program was directed at some of these needs. One project explored the design criteria for an innovative two-stage fluidized bed bioreator in which the three major processesofcell immobilization, biodegradation, and biofilm control were combined in a single unit. Thisinnovative, reliable biological wastewater treatment process and design provides an efficient and environmentally safe waste water treatment system. Two projects explored the fate and transport of agricultural chemicals. One studied the potential impacts that interactions and reactions between herbicides and existing humic materials as they move through the soils toward the groundwater table. The other project studied the behavior of Nitrogen-heterocyclic compounds as they breakdown in the soil and theirpersistencein an aquifer. The fourth project studied the Scioto River buried valley aquifer. This research developed a ground water management model for predicting water quality changes associated with ground water abstraction.

Training was provided to five students enrolled in three disciplines and three colleges at The Ohio State University.

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WATER PROBLEMS AND ISSUES OF OHIO

Water is one of Ohio's most important natural resources. Ohio is bounded on the north by Lake Erie and on the south by the Ohio River and contains other extensive ground and surface waters. Ohio has an adequate supply of water to meet its immediate needs. However, the combination of large, heavily industrialized urban centers; extensive agricultural activities; high volume coal production and large coal reserves; and the demands associated with new energy production continue to cause concern for water quality and water management.

In addition, extreme hydrologic events cause localized problems of both excessive water and water deficiencies at times.

Surface Water

The northern twenty-five percent of Ohio's area drains into Lake Erie, while the remaining area drains into the Ohio River. Runoff from Ohio's streams and rivers averages about 25 billion gallons a day. The state also receives nearly a billion gallons of runoff daily from the neighboring state of Indiana which drains through the Maumee River to Lake Erie; Ohio also has access to additional flows past its boundaries in Lake Erie and the Ohio River that total well over 150 billion gallons of water a day.

Last year, more than 16 billion gallons of water were withdrawn from Ohio's surface sources each day to meet the demands for municipal supplies; rural needs for domestic and livestock purposes; irrigation; and self-supplied industrial needs including cooling water for thermo-electric power generation. Each day these demands account for 60 percent of the available surface waters in the state's streams. Localized shortages develop only during certain dry seasons and periodic droughts.

The combined length of all the streams in Ohio approaches 44,000 miles, which means that there is approximately one mile of stream for each square mile of surface area in the state. In addition, there are more than 50,000 lakes, ponds and reservoirs within the state which have a combined surface area of 200,000 acres. About 6,700 acres occur naturally, while the remainder are man-made impoundments that range in size from small farm ponds to large multipurpose reservoirs.

The reservoirs in the state are used to provide water for many different purposes including municipal, agricultural and industrial supplies; stream flow augmentation; flood control; and recreation. No impoundments in Ohio, other than those on the main stem of the Ohio River, provide water for downstream navigation or hydro-electric power generation. However, there is extensive navigation on both Lake Erie and the Ohio River, and consideration is being given to the installation of low-head hydro-electric generators at several developed dam sites throughout the state.

Flooding is a major problem in Ohio and it affects both urban and agricultural areas. It has been estimated that nearly two million acres of land in Ohio are flood prone. This represents more than seven percent of the total area of the state and includes nearly four percent of those areas classified as urban regions. Average annual flood damages in Ohio vary from year-to-year but amounts to several millions of dollars annually.

Ground Water

Ground water is an important part of Ohio's water resources. Ground water underlies most of the state but is predominant in the glacial drift in the northwest, in the ice-contact and out-wash deposits in river valleys along the border of the glaciated areas, and in the bedrock of the western portions of the state. Ground water supplies are largest in the glacial valley-train deposits in those drainage basins which border the Ohio River including the Ohio, Miami, Little Miami, Scioto, Hocking and Muskingum Rivers. Well yields from these deposits often exceed 500 gallons per minute (gpm), while aquifers in the glacial drift in the northwest and west-central parts of the state produce yields between 100 and 500 gpm. Isolated aquifers in the northeast, northwest and south west have yields between 25 and 200 gpm, while much of the northeast contains aquifers whose yield is between 5 and 25 gpm. With the exception of the valleys along the major streams, most of the aquifers in the area that is tributary to the Ohio River have yields less than 5 gpm.

Seventy-five percent of Ohio's 650 public water supply systems use ground water as their source. In terms of volume withdrawn, however, a lesser share of these supplies comes from ground water, almost a half billion gallons of ground water are withdrawn daily for public water supply purposes, while more than a billion gallons come from surface water sources. However, ground water supplies nearly 80 percent of the rural water needs in Ohio, 32 percent of the irrigation waters and 21 percent of the industrial water demands. Nearly one billion gallons of ground water are withdrawn in the state each day to meet these needs.

Water Quality

It is the water quality, rather than the quantity, that is the more critical and limiting condition associated with the use of both ground and surface waters in Ohio. The ground waters of the state frequently have relatively high, natural mineral contents; but, except for a few local areas, most of these waters are free from man-related contamination. Most complaints are related to increased levels of turbidity, bacterial populations and other substances from improperly sited or poorly constructed or maintained wells. Other problems are related to the spillage and leakage of brines and petroleum at oil wells in the southeastern part of the state; the mis-application of pesticides, herbicides and insecticides in agricultural areas; and the improper siting and operation of solid and liquid waste disposal facilities. Some minor ground water problems are also associated with the excessive use or improper storage of highway de-icing salts.

The dissolved solids concentrations in Ohio's streams range from 120 and 2,500 milligrams per liter (mg/l). The higher concentrations are found in the Tuscarawas, Cuyahoga and Grand Rivers and in other stream reaches below major municipal and industrial out falls or in areas subjected to diffuse source runoff.

Of the 23,000 miles of principal rivers downstream of major urban areas in the state that have been monitored, 16,000 miles, or 70 percent of these streams, meet the current water quality standards. Where problems do exist, they are frequently caused by inadequate municipal wastewater treatment at facilities that need to be upgraded or expanded, or by combined sewer overflows. Substantial improvements in surface water quality have resulted from the development of pretreatment regulations for industrial waste discharges to municipal sewerage systems. Violations of the state's water quality standards occur most often in dissolved oxygen levels; ammonia nitrogen concentrations; the numbers of fecal coliforms; and the levels of heavy metals such as lead, zinc and cadmium.

Acid mine drainage is a major cause of water quality problems throughout the Appalachian Coal Basin in the eastern United States. In Ohio this region extends in a band approximately 50 miles wide in a southwesterly direction from the east-central to the south-central parts of the state. Acid drainage from abandoned and improperly operated or reclaimed coal mined lands causes a loss of water for domestic and industrial uses; the degradation of water quality for recreational purposes; a lethal impact on the aquatic life in a stream; and an accelerated deterioration of highways, railroad bridges and electrical transmission lines and towers. Drainage from abandoned coal mines, both surface and under ground, has impacted around 1,500 miles of streams in 27 counties in southeastern Ohio. Approximately 370,000 acres of abandoned strip mines, 7,000 acres of coal refuse piles and 3,000 under ground mines are contributing to this problem. It has been estimated that four billion dollars would be needed to reclaim the abandoned mines and refuse piles throughout Ohio. Projected revenues from severance taxes earmarked for abandoned mine reclamation comes to about ten million dollars annually. Obviously, the technologic problems and the economic costs associated with the control of acid mine drainage will continue to keep this a major problem of water quality in southeastern Ohio for years to come.

Little detailed information is available on the impacts that diffuse sources of pollution, such as agricultural and urban storm water drainage, have on the quality of water in Ohio's inland streams. One concern with non-point pollution is the sediment that is dislodged from the land surface and carried to the streams. Of greater concern are the pollutants, such as the nutrients, heavy metals and toxic organic substances, that enter the streams attached to the sediments. There has been no need for intensive, non-point source control programs to meet water quality standards where Ohio waters drain into the Ohio River; but several studies are underway in the Lake Erie drainage basin to define the role of agricultural drainage on the water quality in the lake. Much more research and many more demonstration projects on the best management practices for agriculture, silviculture, mining and urban run-off control must be conducted before this problem is fully understood and control measures can be instituted.

The trophic status of several lakes and reservoirs in Ohio as been studied; and the results suggest that the lakes and reservoirs in the sandstone bedrock areas of the state generally have lower trophic levels than those in the limestone bedrock areas or glaciated regions. Water quality was generally good to excellent in most of the lakes and reservoirs surveyed. However, excessive concentrations of copper and other heavy metals, bacteria and other pollutants that are normally associated with urban activities were identified in some of the lakes.

Recent studies on Lake Erie indicate that there has been a reduction in several key pollutants and a gradual, but steady, improvement in the water quality in the Lake during the past few years. Phosphorus is a major pollutant which results in the excessive-growth of algae and other aquatic plants. As these plants die and decay, they deplete the oxygen resources of the Lake. The construction of facilities to remove phosphorus at the municipal wastewater treatment plants which discharge directly to Lake Erie has been a major factor in the reduction of phosphorus loadings and of the subsequent reduction of the anoxic areas within the Lake. Additional work on the control of phosphorus from both diffuse sources and point sources needs to be accomplished, but a significant start has been made.

Bacteria levels have been reduced in the near shore zones where municipal waste water treatment facilities have been constructed. This has permitted regulatory agencies to re-open bathing beaches which were often closed during the period between 1960 and 1970. Concentrations of mercury and pesticides have been reduced substantially, principally because of the federal bans that have been instituted on their manufacture, use and disposal. PCB remains a major challenge, as does the control of sediment and the nutrients, fertilizers and organic chemicals that are attached to it.

Fish populations, including the walleye pike, are beginning to increase again in the lake; but the quality and diversity of fish is still far from what they were in the past. Thermal pollution is a localized problem in some near-shore areas. However, as closed cycle cooling is required on all power generation facilities, the extent of this problem will diminish.

PROGRAM GOALS AND PRIORITIES

The Water Resources Center at The Ohio State University encourages and supports research that is directed at providing information needed to solve the major water problems at the local, state, regional and national levels. The research program at the Center includes basic or fundamental research, problem oriented or applied research, and information dissemination and technology transfer activities.

During FY 1982, the Center, in cooperation with several groups of water-related agencies and officials throughout the State prepared a prioritized list of Ohio's major water resources problems. Based upon this analysis, the following ranking of these problems was developed:

1. POLLUTION FROM DIFFUSE SOURCES - including agricultural runoff; urban runoff; run off from on-site waste disposal systems; runoff from active, reclaimed or abandoned coal and strip mines.

2. CONTAMINATION OF DRINKING WATER SUPPLIES - including surface and ground waters for both urban and rural uses by diffuse and point sources, and by the disposal of toxic and hazardous wastes on the land.

3. TOXIC AND HAZARDOUS WASTE DISPOSAL - including their control, treatment, disposal and impact upon land, water and air resources.

4. POLLUTION FROM POINT SOURCES - including municipal and industrial sources not yet in compliance with their NPDES permits.

5. IMPACTS OF FLOODING AND DRAINAGE - including flood damages, the use of flood plains and alternative structural and non-structural means of controlling floods and reducing flood damages.

6. IMPACTS OF WATER RESOURCES DEVELOPMENTS - including the impacts on various land uses caused by structural and non-structural water resources developments such as the extension of water mains and sewers into rural areas; flood control projects; hydro-electric power generation; water-based recreation; etc.

7. IN STREAM FLOWS NEEDS - including interrelationships among water quality, water quantity and land use practices on the in stream flow needs for fish, wildlife, and recreation and the optimum development and protection of these in stream uses.

8. IMPACTS OF SYNTHETIC FUEL DEVELOPMENT - including requirements for water and impacts of the disposal of wastes from these processes into waters and onto the land.

9. IMPACTS OF ATMOSPHERIC POLLUTION - including the effects of acid precipitation and atmospheric fallout on water quality and the environment.

10. ALLOCATION OF WATER RESOURCES - including the development of contingency plans for the allocation and conservation of limited water supplies among competing water users during periods of low stream flows.

Subsequently, the Directors of the Water Resources Research Institutes in the Great Lakes, Upper Mississippi and Ohio River Basin's met to identify their State problems the major water resources research priorities for the Region. A listing of these priorities is included at the end of this Section of this Report. The focus of the 1989 Ohio Water Research Institute Program was directed at some of these crucial needs.

The project by L. S. Fan entitled "Optimatization of a Novel Two-Stage Fluidized Bed Bioreactor Involving Immobilized Living Cells for Water Treatment" explored the design criteria for an innovative two-stage fluidized bed bioreactor in which the three major processes of cell immobilization, biodegradation and biofilm control were combined in a single unit. This innovative, reliable biological wastewater treatment process and design provides an efficient, less costly and environmentally safe waste water treatment system.

Drs. Traina and Logan of The Ohio State University Agronomy Department were specifically studying the potential impacts that interactions and reactions between herbicides and existing humic materials have on the fate and transport of the herbicides in the groundwater.

Drs. Sims and Traina of The Ohio State University Agronomy Department studied the fate and transport of agricultural chemicals by studying the behavior of Nitrogen-heterocyclic compounds in the subsurface environment.

Ohio State University researchers, Ward of Agricultural Engineering and Bair of Geology, studied the Scioto River Valley buried aquifer to design a model to determine the possible contamination of the aquifer by agricultural chemicals. This research will monitor the water quality of the aquifer by pumping water from the aquifer into ponds for catfish farming.

The technology transfer programs of the Water Resources Center continued to disseminate information about the water resources of Ohio to local and state decision-makers and provided technical assistance to help resolve some of the state's major water problems.

Training on these research projects was provided at Ohio State University to four graduate students in the disciples of Agricultural Engineering, Agronomy, Chemical Engineering, Civil Engineering and Geology. In addition, an undergraduate student from Agronomy gained practical knowledge and training by working on these projects.

REGIONAL RESEARCH PRIORITIES

Great Lakes - Upper Mississippi - Ohio River Region

A. Groundwater contamination

1. Track pollutants through the vadose zone to the ground water and determine their rate of dissipation in the aquifer.

2. Assess the impacts of the disposal of municipal and industrial wastes and effluents on ground water systems.

3. Evaluate sources of recharge of the principal aquifers in the region.

4. Determine the effects of the storage of waste heat in aquifers on groundwater quality.

B. Pollution of lakes and streams from non-point sources

1. Assess relative effectiveness of non-point pollution control "best management practices" to meet the demands of P.L. 92-500.

2. Evaluate the effects of atmospheric fallout and precipitation (acids, toxic metals and hazardous trace organics) on public health and the aquatic environment.

3. Estimate the effects of drainage from land use activities in urban areas on surface water quality.

4. Model sediment transport processes and devise techniques for determining sediment delivery ratios.

5. Determine the relative effectiveness of voluntary programs enhanced by various incentives and regulation as mechanisms of implementing non-point pollution control.

6. Predict the impacts that agricultural technologies will have on surface and groundwater resources.

C. Adverse water resources impacts of energy production and mining.

1. Evaluate the impacts that drainage from mining activities will have on the incursion of acids, toxic metals, radio nuclides and hazardous organic compounds into the environment.

2. Assess atmospheric and aquatic pollution from coal-fired electric generation plants.

3. Assess legal, economic, environmental and social impacts and develop means for resolving water user conflicts associated with siting, constructing and operating energy conversion facilities and mining operations.

4. Examine the potential benefits, public and environmental, from the reclamation of heated waters from power generation.

D. Potential insufficiency of waters for agriculture and rural communities

1. Determine optimal water requirements for crop production and develop practical methods for irrigation scheduling.

2. Evaluate criteria for establishing minimum requirements for the drainage of imperfectly drained soils of the region.

3. Develop water conservation practices and methods for holding and temporarily storing surface and drainage waters for reuse in periods of seasonal suboptimal precipitation.

E. Loss and degradation of water based fish and wildlife habitat

1. Define the functional and economic value of wetlands including ecological and hydrological mechanisms that influence their integrity.

2. Develop acceptable mechanisms, including incentives and legislation, for preserving publicly and privately owned wetlands.

3. Determine the quality and quantity of in-stream flow necessary to maintain an active and viable aquatic biota.

4. Determine the potential and incentives needed to increase wildlife and waterfowl production on private lands.

F. Miscellaneous

Develop the relationship between commercial/commodity and recreational use of the major lake and river systems of the region. Research emphasis should be placed on development of sufficient water-based recreational facilities in urban settings.

SYNOPSIS

Project Number: 02

Start: 07/89 (actual)
End: 06/91 (actual)

Title: Optimization of a Novel Two-Stage Fluidized Bed Bioreactor Involving Immobilized Living Cells for Water Treatment

Investigator: Fan, Liang-Shih, The Ohio State University, Columbus

COWRR: 05D **Congressional District:** Fifteenth

Descriptors: optimization, water treatment, fluidized bed, immobilized cell, phenols, biodegradation

Problem and Research Objectives:

Strict regulations for drinking water quality and industrial effluent pollution will require waste water treatment systems that are more efficient and economical than present methods. Fluidized bed bioreactors are proving to be such a system. This system uses microorganisms to cleanse the water, while it also conserves land and preserves the environment.

Problems encountered in earlier fluidized bed bioreactor systems are the length of time required for biofilm cultivation before start-up; the need for frequent monitoring of particle replenishment; and quality control of the biofilms attached to the particle carriers.

A novel two-stage, three-phase fluidized bed bioreactor has been developed which minimizes the problems of earlier bioreactors and enhances the efficiency of the waste water treatment process.

This research project studied the effects of several operating variables including liquid flow rate, gas flow rate, inlet substrate concentration and temperature on the bioreactor. Furthermore, a generalized process model was developed to simulate the optimum operating conditions for waste water treatment applications.

Methodology:

The overall biodegradation rate of the two-stage fluidized bed bioreactor depends on air-flow rate, bioparticle loading, biofilm properties, influent phenol concentration and liquid flow rate. In addition, the air-flow rate affects the dissolved oxygen concentrations in both stages and it could possibly influence the bioparticle separation between the two stages. To characterize the two-stage fluidized bed, experiments conducted during the research consisted of: 1) characterizing the bioparticle separation between stages of the bioreactor, 2) testing the efficiency of the biofilm control device and 3) conducting biological waste water treatment in the two-stage bioreactor and characterizing its overall performance.

Particle separation was studied using two different sizes of activated carbon particles, i.e., 307 and 714 μm. Several solid-liquid separation devices were tested. These devices were located between the two stages. The criterion for selecting the separation device was established by considering the mechanism of the particle separation which is caused by the liquid linear velocity through the separation device with negligible air-flow effects.

A hydraulic biofilm removal device was used to control the biofilm thickness. Results showed that efficient biofilm removal is dependent upon biofilm thickness at a given air-flow rate. Phenol was the model substrate that was used. It was chosen because of its inhibiting properties and for being a toxic pollutant. Measurements of biofilm thickness, particle holdup, and substrate concentration in both stages are needed to study the behavior of the two-stage bioreactor. Particle holdups in both stages were obtained by the free flow method and biofilm thickness was measured with microscopes. Phenol concentrations were determined by the 4-aminoantipyrine colorimetric method.

Principal findings and significance:

Experiments were conducted to investigate the characteristics of phenol biodegradation in a two-stage fluidized bed bioreactor. The two-stage bioreactor integrates the immobilization and biofilm cultivation, biodegradation and biofilm control functions into a single unit. Performance of this bioreactor is characterized by the biofilm removal efficiency, the particle separation between the two stages and the biodegradation efficiency.

Separation of particles between the two stages of the bioreactor using various baffle configurations were investigated. The one yielding the best particle separation efficiency and stability was employed for comprehensive studies. In this configuration, the baffle serves as the gas distributor for the second stage; and bioparticles with terminal velocity lower than the linear liquid velocity of the baffle region can be selectively entrained into the second stage.

The biofilm removal efficiency of the reactor increases with increasing flow rate. The efficiency also depends on the thickness of the biofilm for the particles to be treated. For a given flow rate, the efficiency is almost constant for large biofilm thicknesses and decreases for small biofilm thicknesses. When the thickness is below a minimum value, however, no biofilm removal takes place. As this minimum value decreases with increasing air flow rate, the ultimate biofilm removal efficiency is higher at higher air flow rates.

Phenol degradation using biological means was conducted successfully in this two-stage fluidized bed bioreactor. Experiments were conducted under different solids holdups, inlet phenol concentrations and liquid flow rates. At a steady state, the outlet phenol concentrations below 1 ppm were obtained for inlet concentrations up to 200 ppm with 26.5 l hour liquid flow rate. The steady-state results reveals that the degradation rates of the two-stage fluidized bed bioreactor are superior to those of single-stage fluidized bed bioreactor.

Under dynamic situations, two phenol removal periods, an adsorption period and a biodegradation period, were identified. In the adsorption period, phenol removal was achieved primarily by adsorption on the large internal surface area of the activated carbon particles. It should be noted that the large adsorption capacity of the bioparticles remained in the first stage of the bioreactor. As time elapsed, biofilm thickness increased and the particles' terminal velocity decreased. Bioparticles which were larger than 60 μm were then entrained into the second stage. The solid holdup of the first stage decreased and eventually all bioparticles were entrained into the second stage. By applying the baffle as designed, particle separation can be achieved automatically as the properties of the bioparticle changed.

In summary, the research completed during this year covers both the practical design and the bioreaction engineering aspects of the two-stage fluidized bed bioreactor for wastewater treatment. The stability of the bioreactor and the longevity of the operation are two primary considerations in the design of this system. Because both are highly dependent upon the stage of the cells and the biofilm thickness, the performances of the biofilm control device and particle separation baffle are very crucial to the effectiveness of the fluidized bed bioreactor. The two-stage bioreactor has been demonstrated to outperform one-stage bioreactor in the aspects of (1) biodegradation efficiency and (2) the continuous operation with least human intervention.

Publications and professional presentations:

(1) "Dynamics of a Novel Two-Stage Fluidized Bed Bioreactor for Wastewater Treatment Applications," paper 168A1 presented at AIChE annual meeting, San Francisco, CA, November 5-10, 1989.

(2) "A Novel Two-Stage, Three-Phase Fluidized Bed Bioreactor Involving Immobilized Living Cells for Wastewater Treatment Applications," paper presented at AIChE spring meeting, Orlando, FL, March 18-22, 1990.

Training:

M.S. Theses

None

Ph. D. Dissertation

None

SYNOPSIS

Project Number: 03

Start: 07/89 (actual)
End: 06/91 (expected)

Title: Effect of Sorption on Biodegradation of Nitrogen-heterocyclic Compounds in Subsurface Materials.

Investigators: Sims, Gerald and Traina, Samuel, The Ohio State University, Columbus

COWRR: 05B **Congressional District:** Fifteenth

Descriptors: ground water, sorption, surface chemistry, biodegradation, subsoil, nitrogen-heterocycles.

Problem and research objectives:

Organic compounds originating from a variety of agricultural and industrial activities are found in surface and ground waters. Predicting the persistence and the transportation of these organic pollutants has not always been successful. One reason for this problem is that even the most unstable organic compounds tend to become persistent when they enter an aquifer. This behavior makes them very difficult to remove them from the aquifer.

This project studied the sorptive processes in the biodegradation of N-heterocyclic compounds in the soil and water. The N-heterocyclic compounds include pyridine, alkylepyridines and quinolas. These compounds are one of the most important classes of groundwater pollutants. Understanding the fate of these compounds and the potential for removing them from aquifers, depends on understanding the factors which control their biological degradation; which is the primary route for natural detoxification of organic pollutants. The literature suggests the microorganisms primarily respond to substrates present as the free aqueous species; and, therefore, sorption may limit the availability of organic compounds for biodegradation. The experiments specifically addressed the role of sorption in the biological degradation of organic pollutants in contaminated subsurface material. The investigation results were then applied to existing fate/transport models to predict the movement of pollutants to ground water as well as to predict the die-off kinetics of contaminants in polluted aquifers.

Methodology:

Identification and determination of heterocyclic compounds in soils and sediments. Pyridine and alkylpyridines were extracted from soil and sediment samples, contributed by Rielly Industries from a contaminated aquifer in Indianapolis, Indiana, with 2 M KCl + 0.1 M KH_2PO_4/H_3PO_4 (pH 2.5) by shaking (sediment/solution ratio = 1:10 w/v) for 30 minutes. The aqueous extract was centrifuged at 10,000 X g for 15 minutes (Teflon lab ware). The supernatant was adjusted to pH 8 with KOH (2M), filtered through glass, and loaded onto a C_{18} solid phase extraction column. Salts were washed through the column with organic free water, and the pyridines are eluted with isopropanol (1ml). Base line separation of virtually all commercially available methyl pyridines was achieved using a Varian 3700 capillary gas chromatograph (GC) with a Carbowax capillary column and a temperature program starting at 65°C and holding for one minute, increasing temperature to 110°C at a rate of 1 or 2°C per minute, and holding at 110°C for five minutes. Thermionic specific (Nitrogen-Phosphorous or NP) detection has been extremely successful for analysis of trace quantities of pyridines. Of the High Pressure Liquid Chromatography (HPLC) systems tested, the most successful HPLC program utilized a gradient of methanol and pH when a C18 column (Applied Bio-systems Spheri-5 RP-18, 220 X 4.6 mm) was used. The pH/ methanol gradient was achieved by varying the ratios of the two mobile phases (a) 40% methanol/ 60% 0.05 M KH_2PO_4, pH 7.5 and (b) 50% methanol/50% 0.05 M KH_2PO_4, pH 4.0. It should be noted that separation by capillary GC was more successful than HPLC in our laboratory.

Biodegradation of Heterocyclic Compounds. In a preliminary experiment to determine if pyridines were degraded in the sediment samples, solid samples were mixed to capacity with organic-free water and incubated aerobically at 25°C in the dark. At regular intervals, sub-samples (1 g) were extracted with acidified KCl (10 ml) as described above, concentrated (to 1 ml) and analyzed by GC. At the beginning and end of the experiment, 50g samples were extracted, and concentrated into one ml of isopropanol. Sediment samples were used as inocula for enrichment media containing pyridine, 2-,3-, or 4-methylpyridine (100 mg L^{-1}) as sole sources of carbon and nitrogen. Isolates were obtained by streaking onto agar media containing the compounds of interest, and testing for the ability to degrade the substrates in liquid media. Growth in liquid media was determined by optical density measurements, calibrated to cell number and biomass (protein). Substrate degradation was determined by GC and HPLC. Isolates were identified by cell morphology and gram reaction, as well as membrane fatty acid analysis. An organism capable of growth on quinoline as a sole source of carbon and nitrogen was previously isolated from a mixed inoculum containing several soils and paper mill sludge. The organism was identified and characterized.

Characterization of Quinoline Degrader. Cell Composition, Morphology and Growth Characteristics. Fatty acid methyl esters were prepared from bacterial cell membranes and quantified by high resolution capillary gas chromatography. The procedure was performed with the Microbial Identification System (MIS; Hewlett-Packard Corp., Avondale, PA.). Mycolic acids were detected by thin-layer chromatography (silica gel (Baker Si250)). The solvent system for

single dimensional development was petroleum ether by 60-90°C) -acetone (95:5, v/v). The optimum pH and temperature for growth were determined in 1000 ug/ml glucose: NH_4^+-N media C:N = 5:1. Growth on inorganic nitrogen sources was tested in 1000 ug/ml glucose-basal salts media supplemented with $(NH_4)2\ SO_4$, KNO_3, or KNO_2 to give a C:N of 5:1. Growth was measured as a function of optical density at 660 μm using a Beckman DU-40 UV-VIS spectrophotometer. Urease activity was determined by growth on Christensen Urea Agar. #Cells were assayed for spore-forming ability by growth on A K Agar #2 with subsequent malachite green endospore staining. Succinate and quinoline grown cells were fixed in 4 percent glutaraldehyde and Sorenson's phosphate buffer, washed with buffer and fixed with 1 percent OsO_4. The cells were encased in agar blocks, which were cut into 0.5 mm square fragments, dehydrated with ethanol, and washed in propylene oxide. The samples were embedded in Epon 812 and sectioned with an MT-1 microtome. Transmission electron micrographs of the sections were obtained on a Philips electron microscope.

Determination of Quinoline Utilization and Degradation. Cells were cultured in liquid basal salts media buffered at pH 8, containing initial quinoline concentrations ranging from 0 to 1000 ug/ml. Growth was measured as a function of protein concentration determined by the method of Lowry. Aliquots collected from cultures containing 200 ug/ml quinoline were loaded onto C_{18} Solid Phase Extraction (SPE) columns. NH_4^+-N in the eluent was determined colorimetrically by the indophenol blue method. The components retained on the column were eluted with isopropanol. Quinoline in the eluent was determined by a Varian 3700 capillary gas chromatograph (GC) with a NP detector. An estimation of the molecular weight of the green molecular weight of the green pigment produced by the isolate was accomplished using a Millipore Immersible Molecular Separator.

Production and Degradation of Metabolites Derived from Quinoline.

Large (800 ml) cultures containing 200 ug/ml quinoline adjusted to pH 8 were incubated at 25° C. Samples were collected over time, and quinoline concentrations in the medium were analyzed as described above. Aliquots (100 ml) were concentrated in 1 ml isopropanol by SPE, as described above.

Samples were analyzed by C_{18} reverse phase HPLC with a UV detector at 254 nm in a mobile phase containing 30:70 methanol: 0.02 M ammonium acetate (pH 6.9). Fractions were collected from the peak of an unknown compound which co-eluted with authentic 2-hydroxyquinoline. Spectral characteristics of the metabolite (UV and fluorescence) were determined. The purified residue was analyzed by Fast Atom Bombardment Mass Spectroscopy (FAB-MS) and Electron Impact (EI)-MS. Growth of the isolate on putative quinoline metabolites was measured by O.D. at 660 nm. The isolate was grown in basal salts media containing 100 ug/ml of one of the following substrates: 2-hydroxyquinoline, 4-hydroxy-quinoline, 8-hydroxyquinoline, 2, 4-dihydroxyquinoline, or 2, 3-dihydroxypyridine.

Adsorption Isotherms. Batch equilibrium isotherms, (24 hour incubation) in 0.01 M $CaCl_2$, pH 7.5, were conducted as follows. Sediment samples or Ca Wyoming Montmorillonite (1g-equilibrated with electrolyte) were used as exchanger phases. Sorbate initial concentration ranged from 0 to 200 μmol/L. Solids were removed by centrifugation (8,000 X G) and filtration (0.22 μm) with a nylon membrane. Quantification of sorbate in solution was achieved using absorbance in the uv or HPLC where appropriate. Mixed sorbant isotherms are being conducted to imitate in situ conditions in the sediment. Single compound and binary mixture isotherms are underway for each compound to be used in later studies.

Principal findings and significance:

Analysis of Sediment Samples. Analysis of sediment samples by GC revealed nineteen substances eliciting response from the Nitrogen/Phosphorous specific detector. Over the course of incubation, most peaks disappeared, and some new peaks appeared. GC/MS analysis of concentrated KCl sediment extracts was performed to reveal the identities of these peaks, most of which were alkylpyridines. The sediment from above was extracted again with methylene chloride and analyzed by GC/MS. Numerous substances, largely alkylpyridines and organic acids were detected.

Heterocyclic Ring Degraders. Six isolates were found to be capable of growth on either pyridine or 2-methylpyridine in liquid medium. Isolates were evaluated as to optimal concentrations of substrates for growth, substrate specificity range, and pH optima. Cultures were subjected to fatty acid analysis and Gram reaction for probable identification. Probable identities were as follows: R-1-Gram positive bacillus (not identified), R-2-Enterobacter cloacae, R-3-Arthrobacter globiformis, R-4-Pseudomonas diminuta, R-5-Xanthomonas maltiphila, R-6-Xanthomonas maltiphila. Some of the organisms were able to use heterocyclic substrates other than those on which they were isolated. Generally the organisms were able to use heterocyclic substrates up to 1000mg/L with growth increasing proportionally as concentration increased. In several cases, the lag period before growth was extended at higher substrate concentrations, presumably due to some toxic effect. Excellent growth rates were obtained at pH 5 and pH 7 for several organisms. Since sorption of the compounds to mineral surfaces is pH-dependent, it should be possible to vary the bio-availability of the substrates by altering pH within the physiological limits for growth of the organisms.

Identification and Characterization of Quinoline Degrader. The capillary gas chromatogram of the fatty acid methyl esters from the unknown bacterium showed a similarity quotient in the MIS for Rhodococcus and R. rhodochrous of 0.682, a good match, with no other matches given. The TLC of the unknown bacterium and Rhodococcus equi yielded single mycolic acid methyl esters in each organism, Rf = 0.55 and 0.5 respectively. No mycolic acids were evident for Arthrobacter crystallopoietes. Based upon the TLC and MIS results the isolate is either a Rhodococcus sp. or a Nocardiasp., however, the organism lacked aerial mycelia, indicating that is likely not a Nocardia sp. Endospore-stained cells showed no evidence of endospore formation. Transmis-

sion electron micrographs of succinate-grown cells showed polyphos-phate and poly-beta-hydroxybutyrate granules (PHB) which are characteristic cell inclusions for Rhodococci . In addition a polymer coating was evident. Conversely, quinoline-grown cells lacked PHB granules or coatings. Optima for pH and temperature were 9.0 and 30-35°C respectively. The isolate used ammonium, or after a lag, nitrate or nitrite as nitrogen sources, suggesting an inducible metabolic system. No urease activity was detected.

Determination of Quinoline Utilization and Degradation. The isolate grew over a wide range of quinoline concentrations (10 to 1000 ug/ml). Maximal biomass production was observed in cultures which initially contained 500 ug/ml quinoline, though there was a long lag period, suggesting this concentration is close to the toxicity threshold. Quinoline at 1000 ug/ml was completely inhibitory. Pigment production occurred during log phase growth, however pigment production was not evident in cultures which had initial quinoline concentration less than 100ug/ml, though quinoline was utilized for growth. Disappearance of quinoline was concurrent with increasing biomass (protein) and increasing ammonium concentration in the medium. This suggested that degradation of quinoline proceeded at least to the point where the heteroatom ring is cleaved and ring nitrogen is released.

Production and Degradation of Metabolites Derived from Quinoline. Quinoline (200 ug/ml) completely disappeared from liquid medium within 46 hours after inoculation. A metabolite which co-eluted with authentic 2-hydroxyquinoline was detected after 24 hours incubation and reached a concentration of 2.1 ug/ml after 46 hours. UV-spectra of the unknown metabolite and 2-hydroxyquinoline showed identical patterns (max =227nm). Similarly, fluorescence emission spectra of the compounds were the same. The FAB-mass spectrum of the unknown had prominent peaks at m/z 146, 100 percent (M)H+ and 168, 23 percent (M)Na+, matching the FAB-MS of 2-hydroxyquinoline. The exact mass of the metabolite (145.0527) was equal to the theoretical exact mass. These results confirm that 2-hydroxyquinoline is the first intermediate in the degradation pathway of quinoline for this strain. The HPLC chromatograms of samples taken later in the incubation (46 and 70 hours) contained other peaks with retention times upstream from the 2-hydroxyquinoline peak, indicating an increase in polarity for these compounds. This would be expected for the products of further degradative reactions. Identification of these potential intermediates is the subject of present research. Of the putative quinoline metabolites tested, only 2-hydroxyquinoline was capable of supporting more than minimal growth. Though 2-hydroxyquinoline was present at 100 ug/ml, no evidence of pigment production was observed, however pigment was produced when grown on 100 ug/ml quinoline. This suggested that the pigment is produced via a side reaction in addition to the formation of 2-hydroxyquinoline. The results of the molecular separator indicate that the green pigment has a molecular weight in excess of 10,000 mass units. Due to the size of this molecule it has been speculated that it was formed through a polymerization of quinoline orametabolic intermediate. Further studies are required to elucidate the structure of this polymer(s).

Sorption Isotherms. Adsorption isotherms for pyridine and quinoline on Wyoming montmorillonite over a range of concentration and pH clearly demonstrate a strong dependence of sorption on pH. Isotherms for mixtures of pyridines on sediment samples are being prepared at pH 7.5 to closely approximate in situ pH (7.45). The results of these isotherms will be used to establish conditions needed in sorption/bioavailability experiments to be performed in the second year of funding.

Publications and professional presentations:

The following presentations were or will be made from the work described above:

O'Loughlin, E. J., S. R. Kehrmeyer, and G. K. Sims. 1989. Isolation characterization and substrate utilization of a quinoline degrading microorganism. Agron. Abstr. 81: 224.

Sims, G. K. , C. Staron, and M. R. Brill. 1990. Degradation of pyridine and alkylpyridines by bacteria isolated from a contaminated aquifer. American Society for Microbiology Annual Meeting. May 13-18, 1990, Anaheim, Ca.

The following manuscript includes in-part work from this project.

O'Loughlin, E. J., S. R. Kehrmeyer, and G. K. Sims. 1989. Isolation characterization and substrate utilization of a quinoline degrading microorganism. Appl. Environ. Micro. (In review)

PH.D. Dissertations

One Ph D. work is in process. It will be completed at the end of the second year of the project.

SYNOPSIS

Project Number: 04

Start: 07/89 (actual)
End: 06/91 (expected)

Title: The Role of Soil Humic Substances-Mineral Complexes in the Adsorption and Transport of Anthropogenic Organic Solutes in Natural Waters

Investigators: Traina, Samuel J. and Logan, Terry J., The Ohio State University, Columbus

COWRR: 05B **Congressional District:** Fifteenth

Descriptors: adsorption and exchange, contaminant transport, ground water quality, pesticides, solute transport

Problem and research objectives:

Widespread contamination of underground water supplies by anthropogenic organic solutes (AOS) has been reported in recent surveys conducted by the USEPA and the Environmental Assessment Council. There is a need for accurate contaminant transport models which predict the leaching of AOS into subsurface environments.

Presently, most existing models have been successful in predicting the leaching of water and non-adsorbing solutes through soils. These models have been less successful in describing the transport of strongly adsorbing substances, such as AOS. These predictions are poor, in part, to the overly simplistic descriptions of AOS adsorption that is common to most transport models. It is particularly inadequate in describing AOS adsorption by soil with a linear partition co-efficient normalized to the organic matter content (K_{oc}), yet just such an approach has been taken by numerous investigators. A large amount of literature indicates that the humic substances (HS) in soil organic matter represents the principal adsorption sites for AOS in soils. Recent studies have shown that the binding of AOS to HS can not be adequately described by single-valued, linear partition co-efficients. This latter research has shown that the following interactions are just as important in controlling AOS adsorption, as are the total quantities of HS in the soil. These include, the chemical composition of the soil solution, the chemical composition of the soil HS, the distribution of HS between the solution and solid phases of the soil, and the interactions of HS with clay minerals to form HS-mineral complexes. Thus the value of K_{oc} is not a constant that can be readily inserted into a transport model. Unfortunately, no systematic study has been conducted to develop a model of the dependence of K_{oc} on the chemical properties of *undissolved* HS, or on the interactions of HS with mineral surfaces and the soil solution surrounding it.

Our objectives are to: 1) examine the sorption of selected, model hydrophobic organic solutes and pesticides by synthetic and natural organo-mineral complexes, 2) determine the effect of organic matter type and mineral type on AOS sorption, and 3) determine the effects of solution composition on AOS sorption.

Methodology:

In the first phase of this study we have divided our efforts into two areas: 1) a more extensive examination of the interactions of adsorbed organic cations and non-ionic organic solutes (NOS) on clays, and 2) initial examination of natural organic matter and NOS on clays. The organic cations used were acridine, and quinoline and these molecules were chosen because they are well defined model compounds which allow us to elucidate the properties of the organo-mineral complex in great detail. The model organic solute was pyrene. Results from this portion of the research will be presented first.

Principal findings and significance:

The surface reactivity of pyrene can be altered by the presence of strongly adsorbed, ionizable aromatic solutes such as quinoline and acridine, which when present on clay minerals, create regions of low polarity. These low polarity environments then allow for the sorption of pyrene through non-polar interactions. Thus, the concentration of sorbed pyrene increased with increased surface excess of quinoline and acridine.

Fluorescence emission spectra of acridine adsorbed by SHCA-1 indicated that the acridinium ion was the dominant surface species even at solution pH values in excess of the pKa for aqueous protonation. Since similar results have been reported for quinoline sorption on $SHCa^{-1}$ (Traina, 1990), it is likely that the $NH\text{-}H^{+}$ ions were the main surface species of quinoline and acridine in the present study.

The pH-dependent adsorption of quinoline and acridine caused an apparent pH-dependent sorption of pyrene. This was not due to a direct effect of solution pH on pyrene but was caused by the effect of pH on the surface concentrations of $NH\text{-}H^{+}$ ions.

In all experiments, the values of log K_{oc} for pyrene sorption were within the range of values reported by Gauthier et al. (1987) for pyrene binding to dissolved humic acids. These values also compared favorably with an organic C partition co-efficient based on the log K_{ow} for pyrene, and with an experimentally measured value of the aqueous pyrene-quinoline association constant.

The extent to which the pyrene sorption in this study was due to adsorption versus partitioning is not known. Measured values of log K_{oc} and a linear sorption isotherm at a quinoline surface concentration of 27.19 cmol kg^{-1}, were consistent with partition phenomena. However, non-linear pyrene sorption at lower surface concentrations of quinoline suggest that some adsorption of pyrene to adsorbed NH may have taken place. Regardless of what the reaction mechanism was, it is apparent that sorbed pyrene was indeed associated with adsorbed quinoline and acridine on the surface of SWy-1, and that the nature of this association (as indicated by the K_{oc} for pyrene sorption) varied with the surface concentration of $NH\text{-}H^{+}$.

The present study was limited to quinoline, acridine and pyrene, but it is likely that analogous results would be obtained in systems containing different organic bases and/or different NOS. The full implications of these co-sorption phenomena on the interactions of organic solutes in natural environments are not clear, however it is evident that such reactions could strongly influence the fate of NOS in subsurface environments low in natural organic carbon.

Soil Organic Matter Experiments: Sorption of soil organic matter to specimen smectites, illites and calcites has been initiated to create organo-mineral complexes. Whereas significant organic matter adsorption has occurred in Ca-clay systems, a much smaller quantity of organic matter was adsorbed by Na-saturated minerals.

The sorption of NOS to the HS-smectite complexes has been similar to the behavior of pyrene sorbed by NH-smectite systems in that the K_{oc} for NOS sorption has been shown to decrease with increased surface coverage of the clay mineral by the HS polymer.

These HS experiments will be expanded in the second part of this study.

Publications and professional presentations:

The first phase of this research has resulted in one research manuscript.

Traina, S.J. and B.M. Onken. 1990. Co-sorption of aromatic N-heterocycles and pyrene by smectites in aqueous solutions. J. Contam. Hydrol. In Press.

Traina, S.J. 1989. Co-sorption of aromatic N-heterocycles and pyrene by smectites in aqueous solutions. National Meeting of American Chemical Society, Miami Beach, Florida.

M. S. Theses:

One student is working on his Master's research which is process.

An undergraduate student is also assisting in this 2-year project.

SYNOPSIS

Project Number: 05

Start: 07/89 (actual)
End: 06/91 (expected)

Title: Development of a Buried Valley Aquifer Management Model

Investigators: Ward, Andrew and Bair, Scott, The Ohio State University, Columbus

COWRR: 04B **Congressional District:** Fifteenth

Descriptors: ground water, flow model, induced stream infiltration

Problem and research objectives:

This research developed a ground water management model for predicting water quality changes in buried valley aquifers. Water quality changes in aquifers may be effected by: ground water abstraction from valley fill aquifers which are influenced by induced stream infiltration and percolation of agricultural chemicals; input-parameter requirements and the sensitivity of predictions to these parameters, and to various physical, biological, and chemical processes. The model is being evaluated at a location along the Scioto River valley aquifer where there is a major industrial abstractor (U.S. DOE), where a commercial aquiculture industry is planned, and where there is highly productive agricultural land along the floodplain overlying the aquifer.

The specific objectives of the study are to: (1) characterize and simulate the normal ground water flow and its interaction with the surface water flow system, (2) evaluate the impact on the aquifer of intensive ground water abstraction, (3) evaluate the influence of surface water quality on ground water quality, (4) evaluate the effect of various agricultural practices on the water quality of the surface and ground water systems within the vicinity of several agricultural research plots, (5) identify control methods for minimizing adverse effects and evaluate their effectiveness, and (6) evaluate the impact of using untreated ground water on various types of aquiculture.

Methodology:

Various types of geologic and hydrologic data are compiled and used to construct maps displaying spatial variations in geologic and hydrologic parameters. These maps consist of a top-of-bedrock map, an isopach map of the glacial/alluvial materials, and potentiometric surfaces showing temporal changes in hydraulic gradients. These data are incorporated into a three-dimensional, finite-difference model of the ground water flow system which is used to predict the relative quantities of water pumped from the wellfield that are derived from the river and from the glacial/alluvial aquifer. In addition to these data, samples of ground water, surface water, and the water produced by the wellfield are collected and analyzed for major ion chemistry. A chemical mass-balance is analyzed to determine the relative quantities of water produced by the wellfield that are derived from the river and from the glacial/alluvial aquifer.

The two independent sets of data are compared and used to design a ground-water management model which is based on additional predictive simulations using the ground water flow model to determine changes in water chemistry due to changes in pumpage schemes.

Principal findings and significance:

Based on available data, maps have been constructed showing the altitude of the top of bedrock and the thickness of glacial/alluvial material. In early March a network of domestic and municipal wells was located which will serve to define the potentiometric surface. In late March and early April a set of water-level data was measured. The data was used to prepare a potentiometric surface contour map. These data were incorporated along with hydraulic conductivity data from pumping tests performed at the wellfield into a preliminary two-dimensional, finite-difference flow model. The model contains 33 rows and 17 columns. External boundary conditions consist of constant-head and constant flux boundaries which are consistent with the natural groundwater flow regime. Internal stresses are applied by the Scioto River and its tributaries and by pumping at the wellfield. The interaction between the river and the unconfined aquifer is accounted for in the model.

Several preliminary simulations have been made. Figure 1 shows the predicted historical potentiometric surface prior to ground water abstraction at the wellfield. Figure 2 shows the predicted potentiometric surface when several of the wells in the wellfield were operated at a combined rate of 10 million gallons per day. The wells are located with 6 grid cells centered at grid coordinate (4,19). Grid cells have dimensions 800 feet by 800 feet. A preliminary sensitivity analysis was performed using the two-dimensional model. The results of this analysis indicate that the model is most sensitive to the spatial distribution of recharge and the vertical hydraulic conductivity of the river bed. The planned refinement of the model into a fully three-dimensional representation will help assess in greater detail the interaction between the river and the aquifer.

Publications and professional presentations:

M.S. Theses:

Development of a Buried Valley Aquifer Management Model Based on Numerical Simulation of Ground-Water Flow and Mixing Analysis of Surface Waters and Ground Waters, Patrick Nortz (in progress)

Figure 1. Potentiometric surface prior to ground water abstraction.

Figure 2. Predicted potentiometric surface with a daily abstraction rate of 10 million gallons.

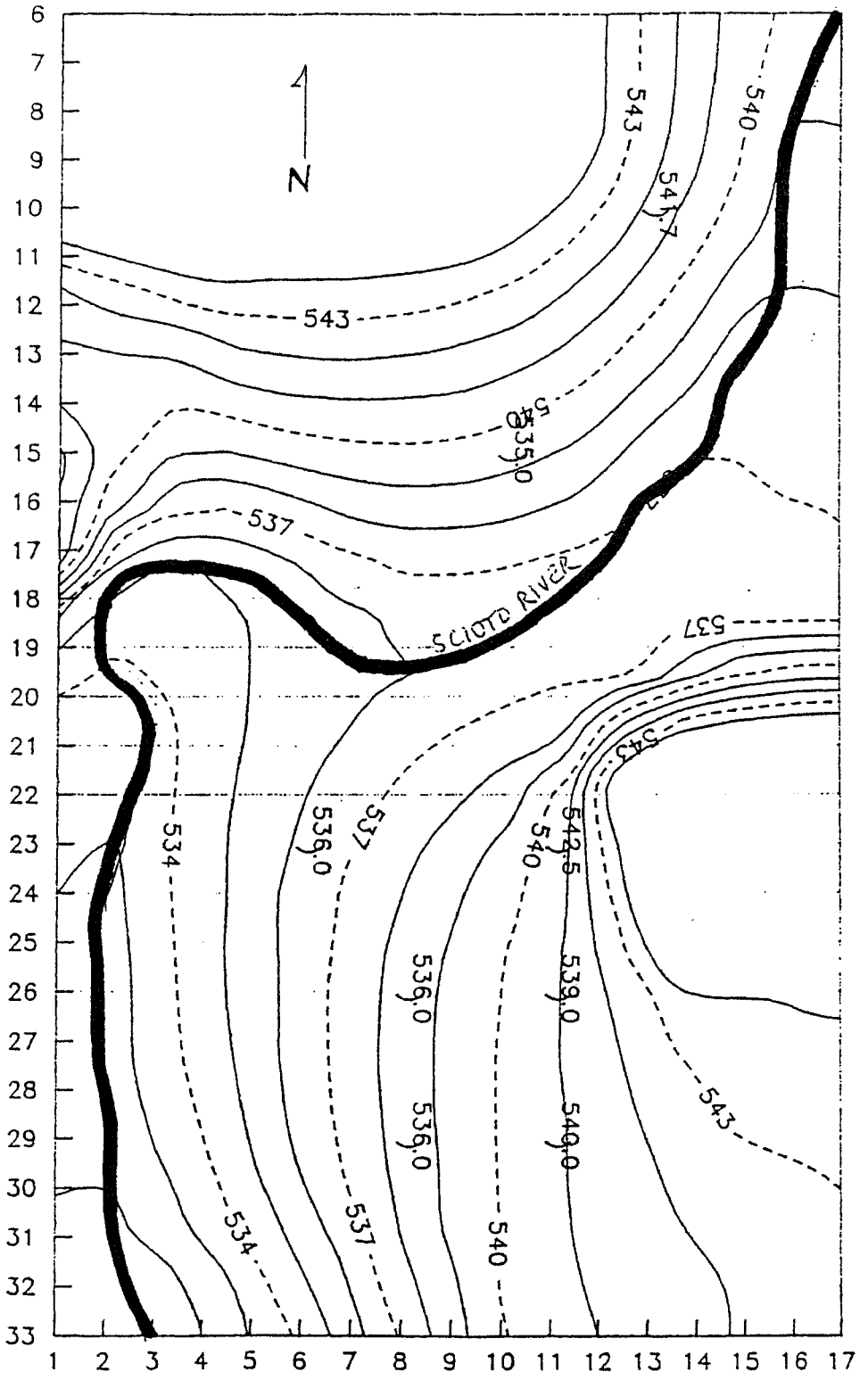

Figure 1. Potentiometric surface prior to ground-water abstraction.

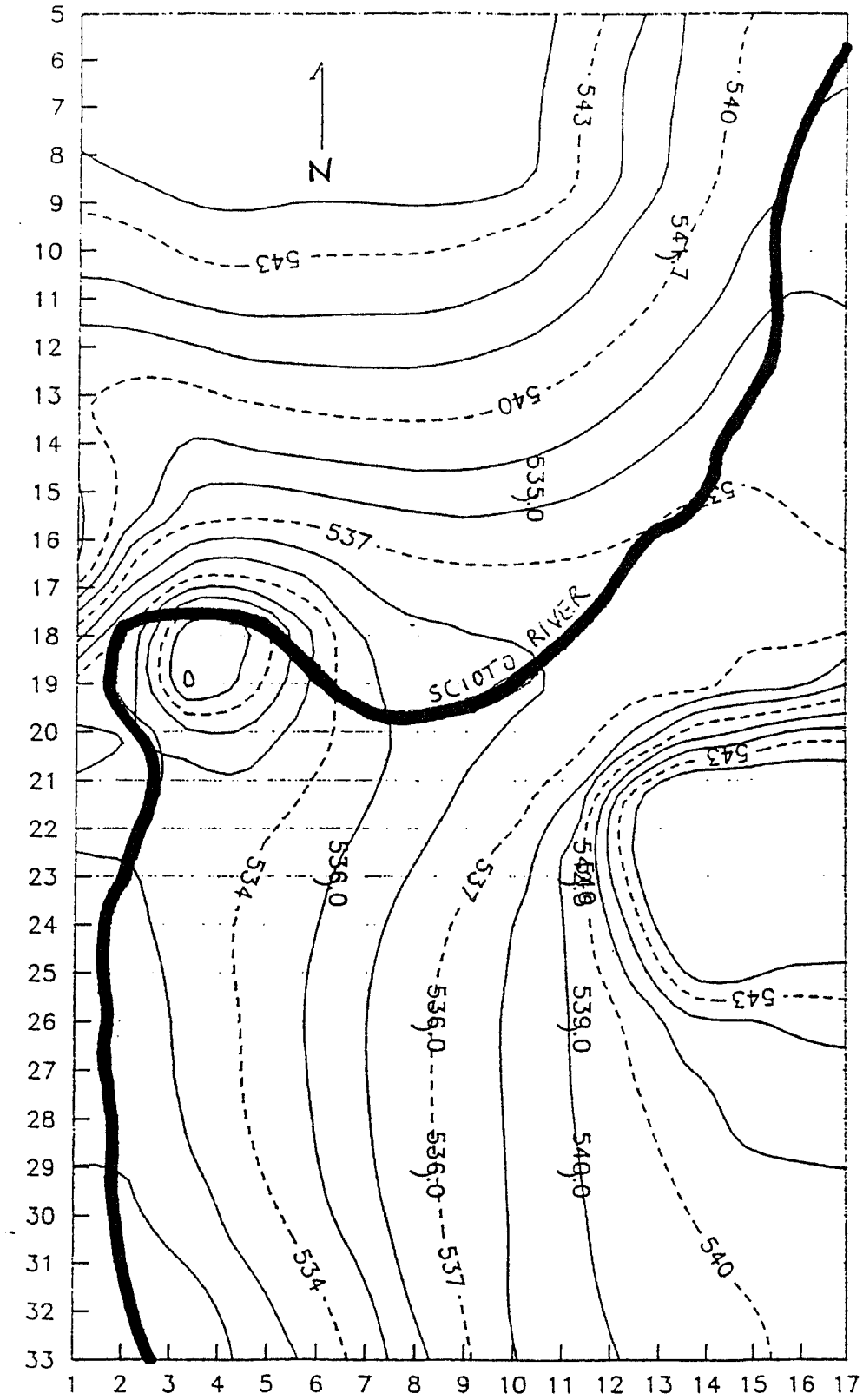

Figure 2. Predicted potentiometric surface with a daily abstraction rate of 10 million gallons.

INFORMATION TRANSFER ACTIVITIES

The Water Resources Center is housed in the Agricultural Engineering Building on The Ohio State University campus. This location provides daily opportunities to work closely and share ideas with researchers in the College of Agriculture as well as the College of Engineering. It also provides a close working relationship with the OSU Agricultural Engineering Cooperative Extension Service.

A series of tasks were continued or initiated to transfer and disseminate information developed by researchers affiliated with the Water Resources Center to a wide range of State, Federal, County and Municipal agencies; to the private sector; to the academic community and to private citizens throughout Ohio.

Water Luncheon Seminars

The Water Resources Center continued to co-sponsor a bi-monthly Water Luncheon Seminar Program for the water resources community in Central Ohio. This program was developed cooperatively with The Ohio Department of Natural Resources (ODNR), the Ohio Environmental Protection Agency (OEPA), the Soil Conservation Service (SCS), the District Office of the United States Geological Survey (USGS), and the Agricultural Engineering Cooperative Extension Service of The Ohio State University. More than eighty water resources professionals from Federal, State, County and Municipal Agencies, the private sector and the academic community attend each meeting to discuss current state, federal and local water policy issues, problems, programs and research results.

In addition to the growing attendance to these meetings, the news worthiness of the information transferred at these meetings is being recognized by the local media and luncheon program information is being transferred to the general public via the press.

The Center not only provides administrative support for the seminar series and mailing costs, but also provides financial support for rental of various media effects and meals.

The moderators, speakers, and topics that were presented during the 1989/90 program year follow.

WATER LUNCHEON SEMINAR, FY 1989

Date	Speaker/(Sponsoring Agency) Location of Meeting	Topic
9/6-8/89	Dr. Tiao J. Chang, Professor Ohio University and Dr. William Mitsch, Professor Director, The Ohio River Basin Consortium Ohio University & Ohio River	Water Quality and Quantity for Ohio River Basin: Planning for the Future: Surface, Ground water, and Water Quality
11/14/89	WRC 25th Anniversary Dr. Andrew Ward, MSEA Professor, Agricultural Engineering Dr. Frank Schwartz, Geology Emmient Scholar Hydrologist at OSU Dr. Robert C. Stiefel Director, Water Resources Center (Water Resources Center) OSU Campus, Agricultural Administration Bldg. Columbus, OH	Program Technical Session Technical Session Perspectives of Past, Present & Future Directions on Water Resources
1/9/90	Mr. Tom Berg Ohio Dept. of Natural Resources (United States Geological Survey) OSU Campus, Fawcett Center Columbus, Ohio	Geologic Mapping and the Future of Ohio
3/13/90	Dr. William H. Anderson OSU Center for Mapping and Kenneth McDonald Wetlands Director, ODNR (Jointly sponsored SCS and Ohio Biological Survey) OSU Campus, Fawcett Center Columbus, Ohio	Remote Sensing & Wetlands
5/8/90	Mr. Richard Sahli Ohio EPA Deputy Director (Ohio Environmental Protection Agency) OSU Campus, Fawcett Center Columbus, Ohio	Implementing Re-Authorization of the Safe Drinking Water Act in Ohio

Water Management Association of Ohio (WMAO)

Since August, 1989 the Water Resources Center has been the communication center for the WMAO. This not-for-profit, 300 member, state-wide organization promotes and supports the development, conservation, control, protection and utilization of the water resources of Ohio for all beneficial purposes. It is the only Ohio organization that is solely concerned with managing Ohio's water. The WRC provides staff support, office space and equipment to WMAO as a portion of the information transfer program.

The Midwest Ground Water Quality Protection Challenge

The Ohio Water Resources Center jointly sponsored a regional conference on ground water quality in November 1989. This Midwest Ground Water Quality Protection Conference was held in St. Charles, Illinois. The purpose for this conference was to share information concerning the implementation of federal and state ground water strategies and to develop a consensus among midwestern states in terms of ground water management and recommendations for the development of a comprehensive regional plan. It also reviewed the status of the EPA National Pesticide Survey and Pesticide Management Plan development in midwestern states. Legislators, legislative aides, agency personnel and individuals with an interest in regional and federal ground water quality and protection measures were invited.

The Ohio Water Atlas

In cooperation with Kent State University's Geography Department, the Ohio State University School of Natural Resources and the Water Resources Center, a preliminary survey was conducted to establish the need for a State Water Atlas. This was done by reviewing the maps that are available in the state through state and federal agencies. More than 150 maps were identified, detailed and classified, and this information was computerized for future reference. Prototypes of maps for future planning were also designed by Kent State. A meeting with the state's leading representatives in water was held to clarify the need, purpose, and direction this activity should take. Continuation of this activity includes communicating with the OSU Center of Mapping and the ODNR learning what information either or both could readily provide and what information is needed to get additional information or mapping data.

Water Resources Center Library

The Water Resources Center has maintained a library of water resources related publications since its establishment in 1965.

Information Dissemination Activities

The Center continues to meet with the leading water resources officials in the state to share information on current water management and policy issues; to seek continued support for the water research program and to disseminate the information and technology developed throughout the state and region.

A newsletter, WATER has been developed and publication started in FY 1988. It focuses on Ohio's water research, technology, issues, legislation in process, education and Center activities. It has a wide circulation that includes public officials, water managers state-wide, university researchers throughout Ohio and the nation, as well as the general public. It has been well received. The editor is Mrs. Carol Moody, who is also the secretary for the Center.

Consultation and Collaboration Activities

The Center's Director has continued to meet with the leading water resources officials in the state for the purposes of consultation and collaboration to identify the major water problems and the research needs of the state and region; to share information on current water management and policy issues; to seek continued support for our water research program and to disseminate the information and technology developed through this program and others at the universities throughout the State and Region.

The Director has been appointed by the Governor of Ohio to serve on the Ohio Water Advisory Council, a statutory commission that advises the Water Division of the Ohio Department of Natural Resources.

The Director continues to serve on the Board of Directors to the Ohio River Basin Research and Education Consortium and he was a member of the 1989 Symposium planning committee. The program was held September 6-8 at the Ohio University, in Athens, Ohio.

The Director is the Lead Delegate to the Universities Council on Water Resources (UCOWR) and is a past member of the Board of Directors; he serves on the Water Programs Public Advisory Group to the Ohio Environmental Protection Agency and is a member of the Toxics Technical Advisory Committee; and he is a member of the Ohio Inter-Agency Water-Use Data Coordinating Committee for the Ohio District of the U. S. Geological Survey.

COOPERATIVE ARRANGEMENTS

Program Development

A call for pre-proposals for the Fiscal Year 1989 State Water Resources Research Program was mailed to research administrators and qualified faculty investigators at over 40 private and public colleges and universities throughout Ohio in mid-November, 1988. This announcement, which is included as Attachment 1 in the Appendix, contained the research priorities identified for the major water problems in the Great Lakes, Upper Mississippi and Ohio River Basins by the Water Resources Research Institutes in the Region. A more detailed listing of these priorities is includes as Attachment 2 in the Appendix.

The announcement also required interested researchers to request a copy of the Preliminary Proposal Application Form which was to be completed and returned to the Water Resources Center in mid-January, 1989. The completed distribution list for this mailing, which contains over 250 names, is included as Attachment 3 in this program.

Pre-Proposals/Federal Guidelines

Preliminary Proposal Application Forms were requested by and sent to twenty-eight investigators and research administrators at fifteen colleges and universities in Ohio. One of those colleges responding was Central State University, an Historically Black University, which submitted a pre-proposal application for inclusion in the 1989 selection process. In addition to the application form which is Attachment 4 in the Appendix, a list of the federal guidelines for the Program, which is Attachment 5 in the Appendix, and a list of the investigators who requested the form is included as Attachment 6 were also enclosed.

Evaluation/Selection Procedures

Nineteen pre-proposals from ten universities and colleges throughout the state were submitted for evaluation and consideration. These pre-proposals were subjected to a review by all of the members of the Water Resources Center's Advisory Committee. In addition, the nineteen pre-proposals were distributed to the various divisions within the three principal state and federal water-related agencies in the State, by the representatives of these agencies who serve on the Advisory Committee, requesting that the divisions review the proposals. The three agencies included in this evaluation were the Ohio Department of Natural Resources, the Ohio Environmental Protection Agency, and the District Office of the United States Geological Survey.

The results of these reviews were presented at a meeting of the Advisory Committee where this panel selected nine of the pre-proposals and instructed the Center's Director to request fully developed proposals from the investigators for the Committee's further consideration.

All nine of the selected pre-proposals were developed more fully and were re-submitted for consideration. The proposals were subjected to a technical review by at least three qualified evaluators selected by individual members of the Water Resources Center's Advisory Committee. Many of these evaluators were from state and federal agencies or Battelle Memorial Institute.

The results of these reviews were presented at a meeting of the Advisory Committee and this panel ranked the leading five proposals in the order they felt would best meet the needs and objectives of the Water Resources Center's program. The Advisory Committee then instructed the Center's Director to incorporate as many of these projects as Federal funds would permit into the FY 1989 Program, and to develop a project for information transfer for the Center. There was only enough Federal monies to support four projects.

The membership of the Water Resources Center's Advisory Committee, which includes representatives from five colleges and eleven departments of The Ohio State University and representatives of the three principal water-related state and federal agencies is included as Attachment 7 in this report.

Regional Cooperative Initiatives

The four projects selected for this program were compared with the FY 1989 Program synopses of the projects included in the programs of the other Water Resources Institutes in the Great Lakes, Upper Mississippi and Ohio River Basin to ensure that there was no duplication of efforts in the Region's research programs.

The Ohio State University has agreed to continue as a Charter Member of the Ohio River Basin Research and Education Consortium, and the Director of the Water Resources Center will continue to serve as one of the University's three representatives to the Consortium. In addition the Director is on the planning committee for the Consortium's 1989 annual meeting which will be held at Ohio University in September, 1989.

The Director has also been appointed by the Governor of the State of Ohio to serve on the Ohio Water Advisory Council.

Program Management

At least once each quarter, the Director contacts the Principal Investigator on each research and information transfer project to discuss progress made during the quarter and to discuss the next quarter's plan of activities. At this same meeting budget details are reviewed and discussed, and necessary operating and reporting procedures to the Water Resources Center and to The Ohio State University Research Foundation's business office are described. Progress Reports or Completion Reports will be prepared for each Project by the Principal Investigators and will be used by the Program Director to prepare the Program Final Report.

All of the investigators are urged to publish the results of their findings in the technical literature of their major disciplines and in other journals that are appropriate to the topic of their research. They are also encouraged and invited to present their findings at the Water Luncheon Seminar that is a part of the technology transfer activities of the Center.

The manuscripts that constitute the project completion reports are first reviewed by the Director of the Water Resources Center. As needed, the Director seeks the advice and council of appropriate state, federal and university scientists for methods of enhancing the value of the technical completion reports to the water-related community in the state and in the region.

WATER RESOURCES CENTER ADVISORY COMMITTEE

COLLEGE OF ENGINEERING

1. Dr. Vincent T. Ricca
   Civil Engineering

2. Dr. Liang-Shih Fan
   Chemical Engineering

3. Dr. Robert C. Stiefel
   Director
   Water Resources Center

4. Dr. Brian Wilde
   Metallurgical Engineering

School of Architecture

5. Dr. Steven I. Gordon
   City and Regional Planning

6. Dr. John W. Simpson
   Landscape Architecture

COLLEGE OF BIOLOGICAL SCIENCES

7. Dr. Robert M. Pfister
   Microbiology

8. Dr. Jeffrey Reutter
   Lake Erie Programs

9. Dr. David Culver
   Zoology

10. Dr. Bruce Vondracek
    Ohio Cooperative
    Fisheries Unit

COLLEGE OF MATHEMATICAL AND PHYSICAL SCIENCES

11. Dr. E. Scott Bair
    Geology and Mineralogy

COLLEGE OF AGRICULTURE

12. Dr. Terry J. Logan
    Agronomy

School of Natural Resources

13. Dr. Robert L. Vertrees
    Resources Management

COLLEGE OF MEDICINE

14. Dr. John R. Wilkens, III
    Preventive Medicine

ADMINISTRATIVE MEMBER

15. Mr. Gun Seren
    Ohio State University
    Research Foundation

OHIO ENVIRONMENTAL PROTECTION AGENCY

16. Dr. John F. Estenik

OHIO DEPARTMENT OF NATURAL RESOURCES

17. Dr. William Mattox

UNITED STATES GEOLOGICAL SURVEY

18. Mr. Steve Hindall
    District Chief

TRAINING ACCOMPLISHMENTS

The following tabulation shows, by fields of study and training levels indicated, the numbers of individuals participating in projects that were financed in part with this grant.

Training Category	**Training Level**				
	Undergraduate*	Master's Degree	Ph.D. Degree	Post - Ph.D.*	Total
College of Agriculture					
—Agricultural Engineering		1			1
—Agronomy	1		1		2
Engineering					
—Chemical			1		1
College of Mathematical and Physical Sciences					
Geology and Mineralogy		1			1
TOTALS	1	2	2		5